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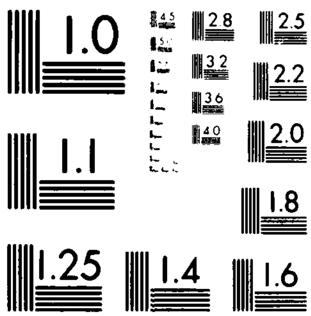
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Report No. CG-D-61-79

13

TOWBOAT MANEUVERING SIMULATOR
VOLUME I - USERS GUIDE

PETER VAN DYKE

FINAL REPORT

MAY 1979

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
United States Coast Guard
Office of Research and Development
Washington, D.C. 20590

NOTICE

METRIC CONVERSION FACTORS

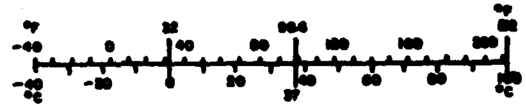
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Technical Report Documentation Page

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7. Author(s) Peter Van Dyke		8. Performing Organization Report No. 7909-1
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16. Abstract

The Towboat Maneuvering Simulator consists of a mathematical description of the hydrodynamic response of an integrated river tow embodied in a computer program running continuously on a computer, with a control console and other graphic and hard copy devices attached for input and output. It is thus a real time, interactive simulator, constantly responding to console commands and immediately updating the console displays.

This volume describes the use of the simulator, provides a block diagram of the program flow, and presents sample input and output.

17. Key Words Towboat Maneuvering	18. Distribution Statement Document is available through the National Technical Information Service, Springfield, VA 22161.

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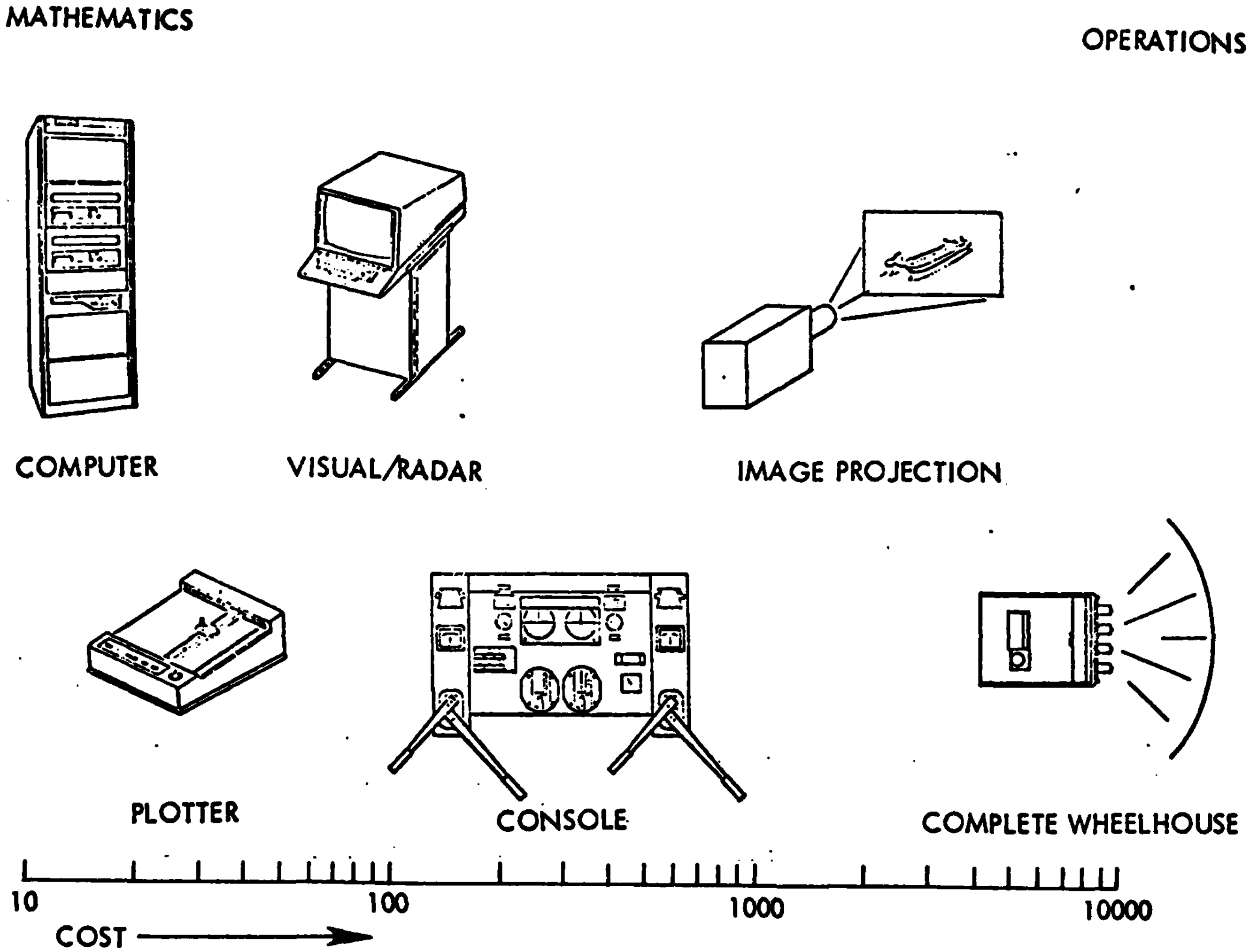
TOWBOAT MANEUVERING SIMULATOR
USER'S GUIDE

1.0 GENERAL DESCRIPTION

The Towboat Maneuvering Simulator consists of a mathematical description of the hydrodynamic response of an integrated river tow embodied in a computer program running continuously on a computer, with a control console and other graphic and hard copy devices attached for input and output. It is thus a real time, interactive simulator, constantly responding to console commands and immediately updating the console displays. Figure 1 illustrates the cumulative relative cost of a typical simulator as more operator-specific equipment is added to the basic mathematical model. The three order-of-magnitude increase in cost is a result of the image projection equipment required to provide visual displays. Typical problems which can be run are also shown in this figure.

Figure 2 shows the components of the simulator. All of the components except the console were supplied by the U.S. Coast Guard, and the console was designed and constructed by HYDRONAUTICS, Incorporated.

The logic flow of the computer program is illustrated in Figure 3. The programs are described in detail in Volume II of this report.



ENVIRONMENTAL - WIND, WAVES, CURRENT
SHIP CHARACTERISTICS - DESIGN ANALYSIS, BOW THRUSTER
CHANNEL / PORT CONFIGURATION - BRIDGES, LIGHTS, MOORINGS
EMERGENCY MANEUVERS
EQUIPTMENT FAILURE

FIGURE 1 - SIMULATOR PROBLEMS

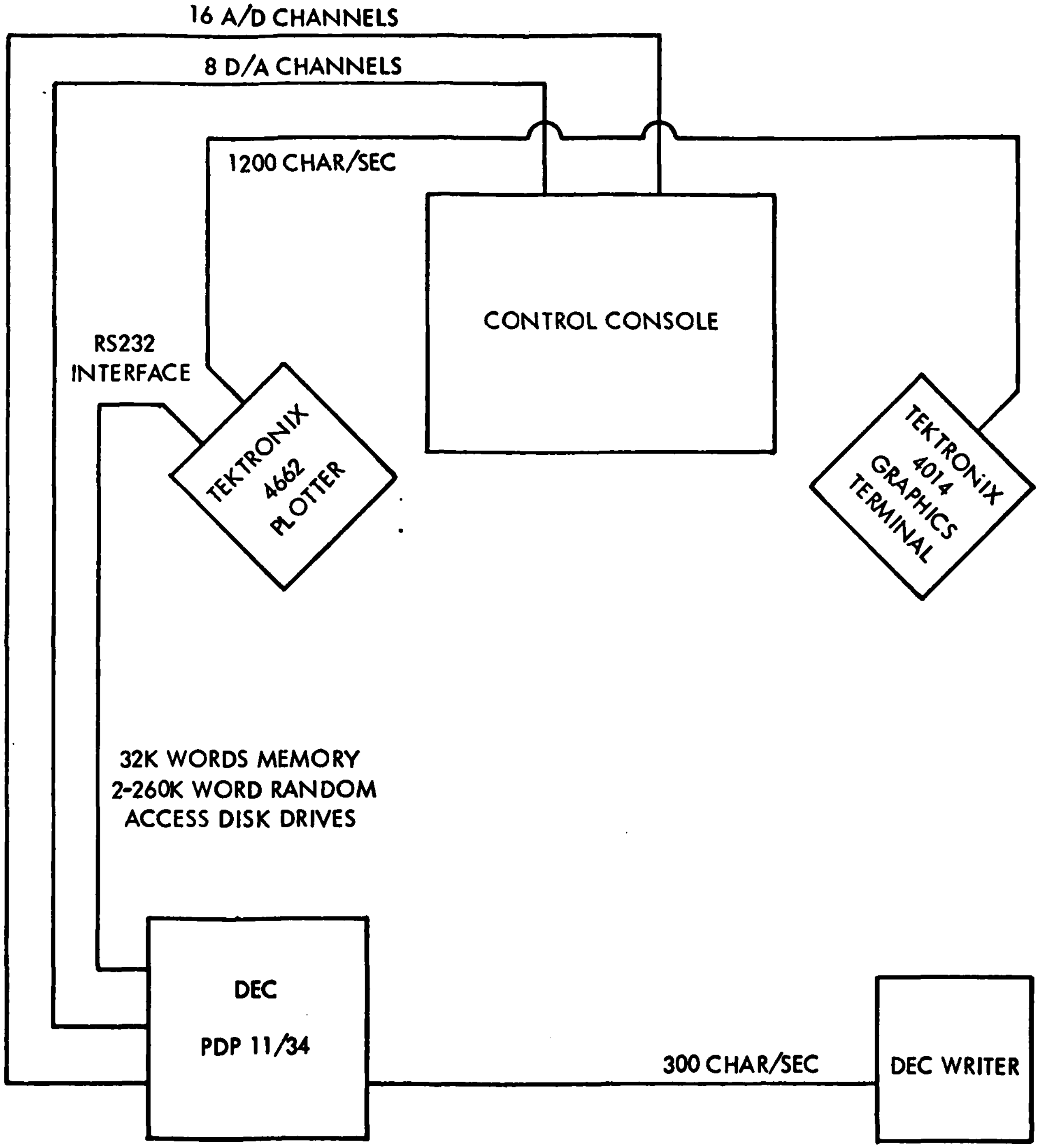


FIGURE 2 - SIMULATOR HARDWARE

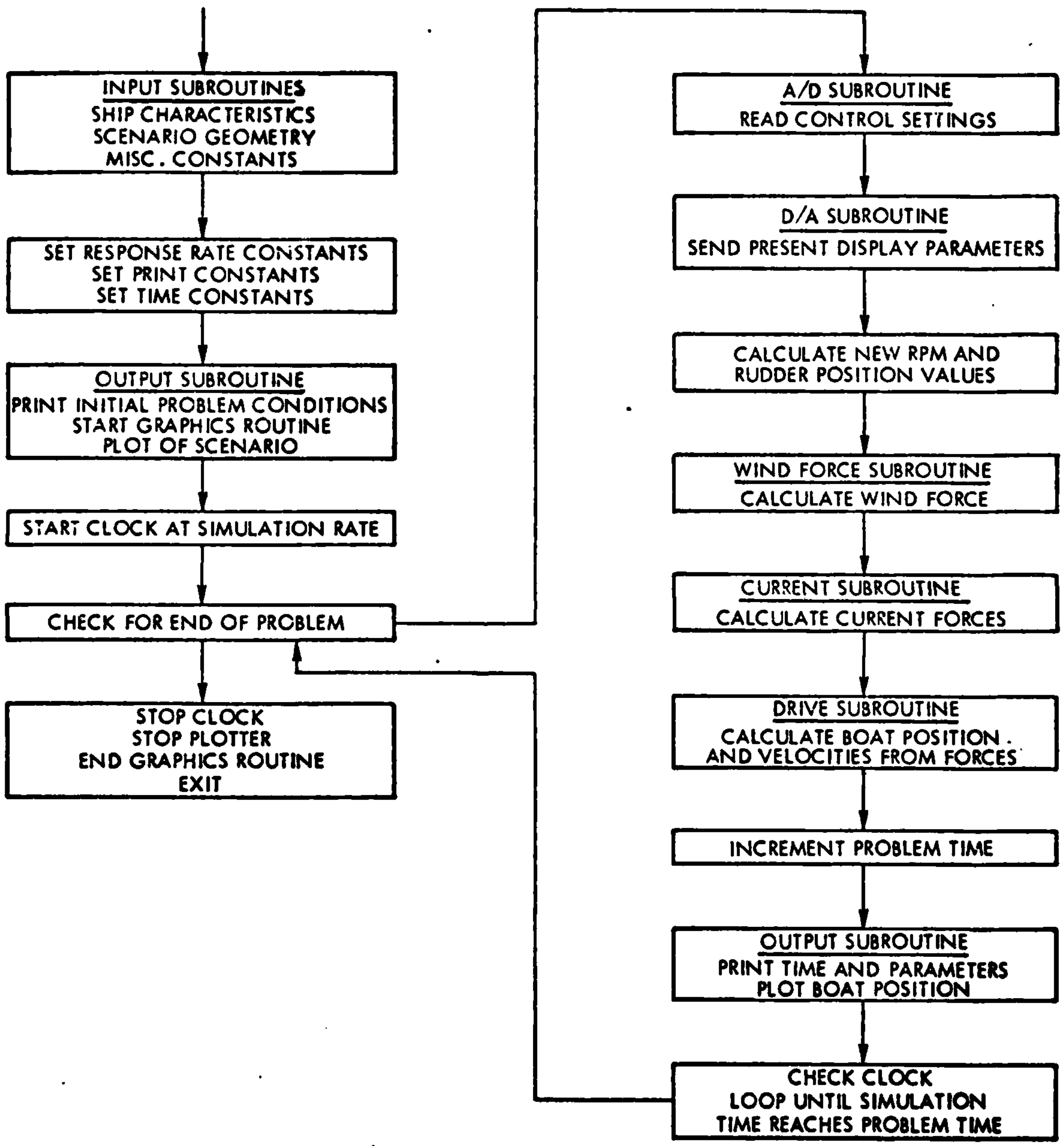


FIGURE 3 - COMPUTER PROGRAM FLOW

2.0 CONSOLE DESIGN

The console design was based on the console in a towboat built by Dravo Corporation. Drawings for the console and the control handles were supplied by Dravo to HYDRONAUTICS to assist in our design. Figure 4 is a picture of the actual console on which our design is based; Figures 5 and 6 show the layout and overall dimensions.

FIGURE 4 - TOWBOAT CONSOLE

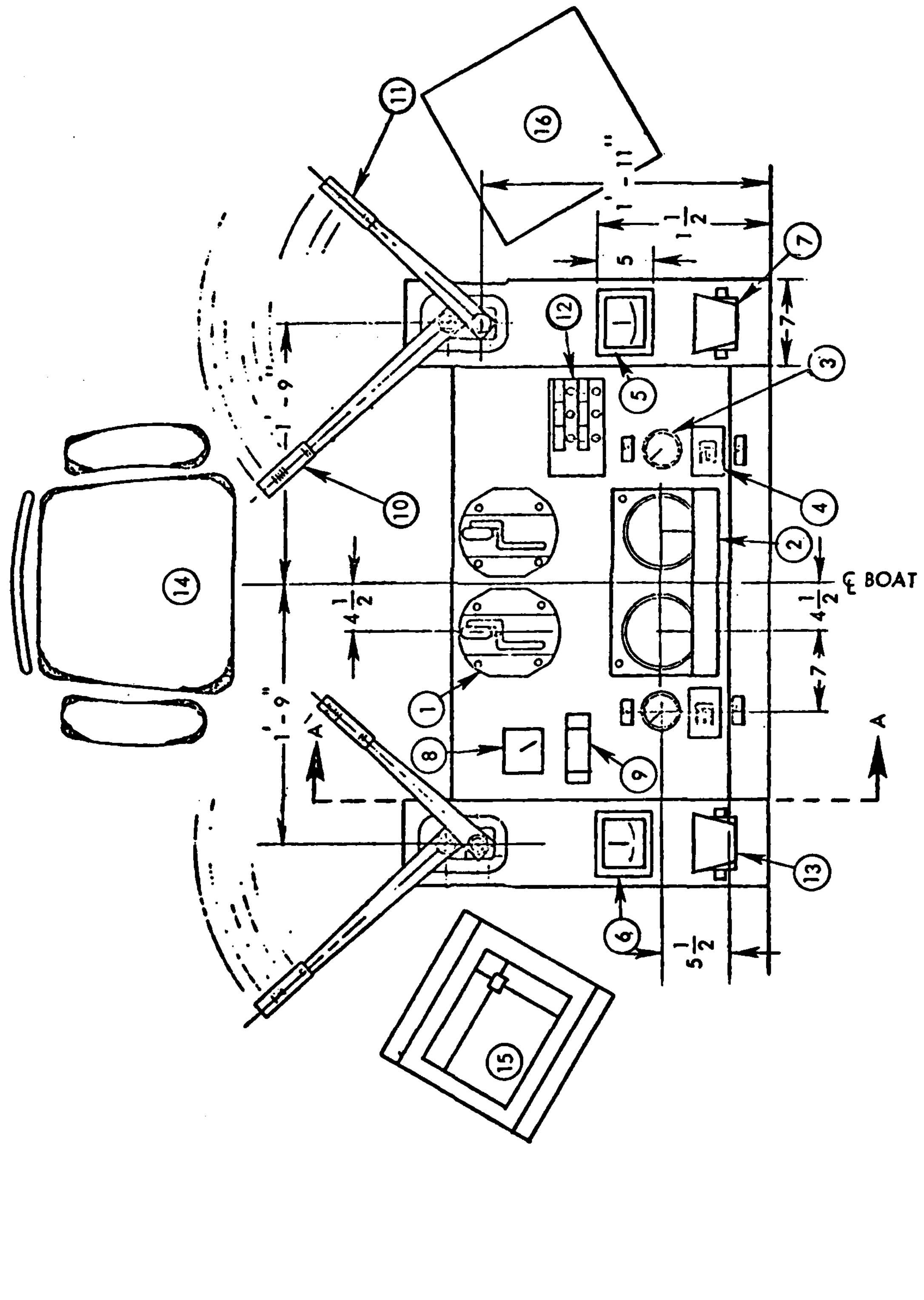
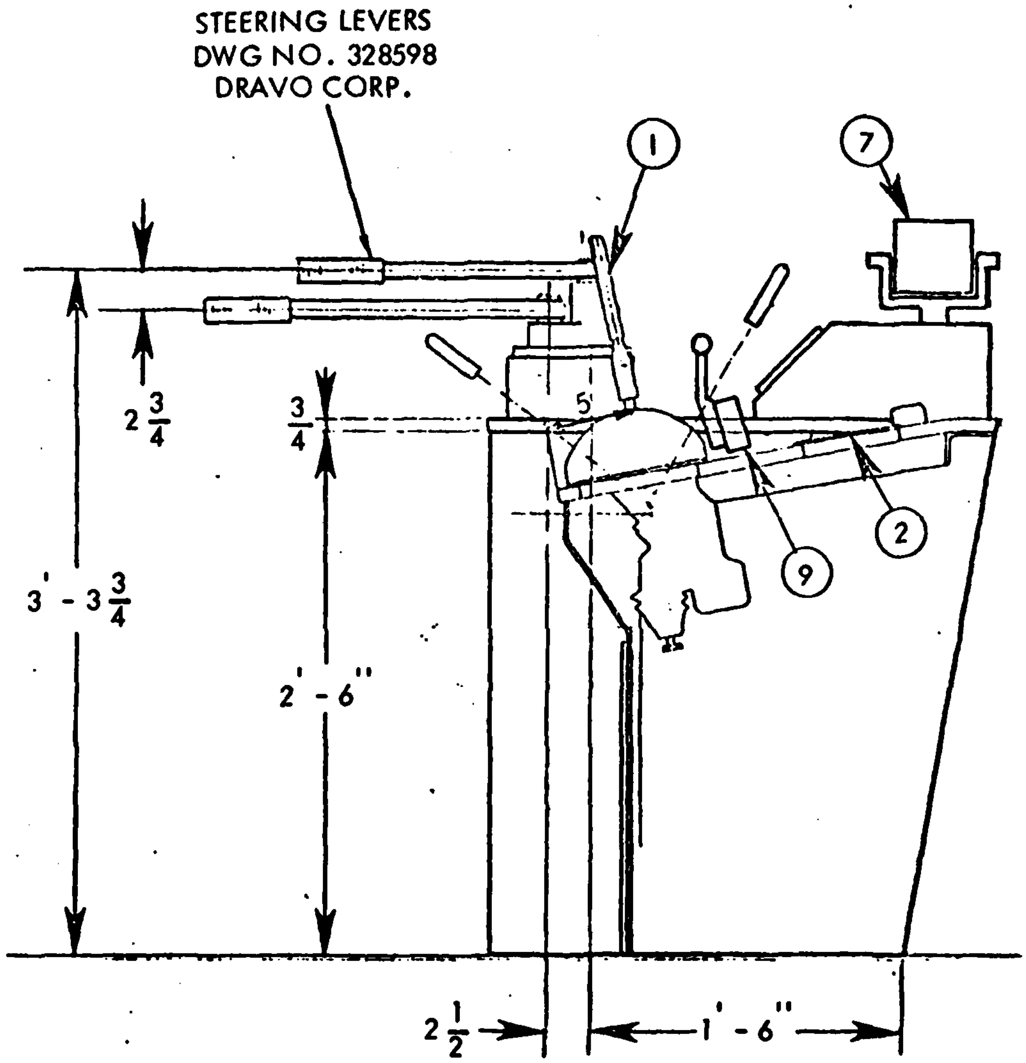


FIGURE 5 - SIMULATOR CONSOLE



SECTION A-A

FIGURE 6 - SIMULATOR CONSOLE

3.0 SIMULATOR INPUTS

Input data on initial conditions, ship characteristics, and scenario definition come into the problem through the three input subroutines. These are described in Volume II of this report. Figure 7 illustrates typical initial conditions, ship, and scenario definitions which can be combined to produce a specific problem. For example, using DTQ03, DTR31, and DTS01 we would have the EXXON NASHVILLE in the Berwick Bay Bridge Scenario, moving up-river with the simulation at twice real time. The scenario input routine contains the waterway geometry, current, and wind conditions. The ship routine contains all coefficients and parameters for the tow to be used. The initial condition routine describes initial position, speed, rpm and rudder settings, and time constants for the tow in the scenario. The ship, current, and wind data necessary for these routines is described in Volume III of this report. Figure 8 lists the other inputs and outputs; the inputs all come from the console and are as numbered in Figure 5:

Port RPM Ordered	Figure 5 - 1 left
Starboard RPM Ordered	1 right
Steering Rudder Ordered	10
Flanking Rudder Ordered	11
Bow Thruster RPM Ordered	9
Stop Switch	12

Section 8, Scenario Parameters, provides specific descriptions of many of the variables in the input routines which are used to set up the operating geometry.

```
!THIS COMMAND FILE LISTS THE EXAMPLES WHICH MAY BE RUN
!BY COPYING THE FILE DTQXX.FOR TO DTL10.FOR, COMPILING
!DTL10, AND RUNNING THE COMMAND FILE MAT10.COM
!
!
!   XX    DESCRIPTION OF INITIALIZATION FILE
!
!   01    BERWICK BAY BRIDGE DOWNRIVER (2 X T)
!   02    BERWICK BAY BRIDGE DOWNRIVER
!   03    BERWICK BAY BRIDGE UPRIVER (2 X T)
!   04    BERWICK BAY BRIDGE UPRIVER
!
!
!   21    TANKER MANEUVERING IN PORT
!   22    TANKER MANEUVERING IN PORT (4 X T)
!
!
!   31    WILKINSON POINT DOWNRIVER (2 X T)
!   32    WILKINSON POINT UPRIVER (2 X T)
!
!THIS COMMAND FILE LISTS THE EXAMPLES WHICH MAY BE RUN
!BY COPYING THE FILE DTRXX.FOR TO DTM10.FOR, COMPILING
!DTM10, AND RUNNING THE COMMAND FILE MAT10.COM
!
!
!   XX    DESCRIPTION OF SHIP FILE
!
!   01    EXXON TENNESSEE
!
!
!   21    TWIN SCREW TANKER
!   22    SINGLE SCREW TANKER
!
!
!   31    EXXON NASHVILLE
!
!THIS COMMAND FILE LISTS THE EXAMPLES WHICH MAY BE RUN
!BY COPYING THE FILE DTSXX.FOR TO DTN10.FOR, COMPILING
!DTN10, AND RUNNING THE COMMAND FILE MAT10.COM
!
!
!   XX    DESCRIPTION OF SCENARIO
!
!   01    BERWICK BAY BRIDGE
!   02    BERWICK BAY BRIDGE NO CURRENT
!
!
!   21    DEEPWATER PORT
!
!
!   31    WILKINSON POINT
!   32    WILKINSON POINT NO CURRENT
!
!
```


FIGURE 7 - SAMPLE INPUTS

A/D INPUTS
PORT PROP RPM ORDERED STBD PROP RPM ORDERED STEERING RUDDER ORDERED FLANKING RUDDER ORDERED BOW THRUSTER RPM ORDERED STOP SWITCH
D/A OUTPUTS
PORT PROP RPM STBD PROP RPM STEERING RUDDER ANGLE FLANKING RUDDER ANGLE BOW THRUSTER RPM RATE OF TURN HEADING ANGLE
PRINTER OUTPUT
TIME X,Y POSITION RPM PORT, RPM STBD, THRUSTER RPM SPEED OVER BOTTOM HEADING, TURNING RATE STEERING RUDDER, FLANKINGRUDDER ANGLES SIDESLIP ANGLE RELATIVE TO BOTTOM
GRAPHIC OUTPUT
PLOTTER - SCENARIO, 30 SEC POSITION SCREEN - SCENARIO, 10 SEC POSITION

FIGURE 8 - COMPUTER PROGRAM INPUTS AND OUTPUTS

4.0 SIMULATOR OUTPUTS

The simulator outputs are given in Figure 8. The console outputs are numbered in Figure 5 as follows:

Port Propeller RPM	Figure 5 - 2 left
Starboard Propeller RPM	2 right
Steering Rudder Angle	5
Flanking Rudder Angle	6
Bow Thruster RPM	8
Rate of Trun	13
Heading Angle	7

Printer Output is illustrated in Figure 9.

The Berwick Bay Bridge problem is described in Figures 10 through 12. The scenario geometry and current specification scheme for this problem is illustrated in Figure 13. A series of 30 stations at Position X, Y with length R at angle α are specified, and the currents at 8 evenly spaced positions at each station are specified by velocity V_c and direction χ_c. The figure shows the positions of the 30 stations. The current values and directions are as given in Volume II, in the listing of DTN10.

Graphic Output is illustrated in Figures 14 through 16. The only difference between the plotter and screen output is the frequency of boat position, as selected by the program.

01-BERWICK BAY BRIDGE DOWNRIVER (2 X T) SAMPLE RUN NUMBER 2 30-MAR-79

TIME(H.M.S)	X	Y	RPM P	RPM S	SPEED	HEADING	RATE	RUDDER SETTINGS		BETA	TRPM
0. 0. 0	14355.	3300.	100.00	100.00	7.00	216.00	0.000	0.0	0.0	0.00	0.00000
0. 0.20	14158.	3156.	130.47	130.37	7.39	215.44	-0.050	5.2	0.1	359.29	-0.01709
0. 0.40	13951.	3006.	130.57	130.47	7.73	214.09	-0.082	5.9	0.1	358.55	-0.01660
0. 1. 0	13734.	2852.	130.57	130.27	8.01	212.17	-0.110	7.6	0.1	357.79	-0.01709
0. 1.20	13507.	2696.	130.47	130.37	8.26	209.87	-0.120	5.9	0.1	357.22	-0.01709
0. 1.40	13271.	2542.	130.47	130.37	8.46	207.39	-0.127	5.9	0.1	356.73	-0.01709
0. 2. 0	13025.	2391.	130.47	130.37	8.61	204.76	-0.131	3.7	0.1	355.97	-0.01709
0. 2.20	12770.	2246.	130.57	130.47	8.71	202.31	-0.117	3.7	0.1	355.80	-0.01709
0. 2.40	12509.	2108.	130.57	130.37	8.78	200.00	-0.115	3.7	0.1	355.41	-0.01709
0. 3. 0	12241.	1978.	130.57	130.37	8.83	197.71	-0.113	2.6	0.1	355.46	-0.01758
0. 3.20	11968.	1857.	130.57	130.47	8.87	195.46	-0.111	2.5	0.1	354.86	-0.01758
0. 3.40	11689.	1746.	130.57	130.47	8.89	193.41	-0.092	0.4	0.1	354.04	-0.01758
0. 4. 0	11406.	1646.	130.57	130.37	8.87	191.05	-0.153	8.1	0.1	353.63	-0.01758
0. 4.20	11120.	1559.	130.47	130.47	8.82	187.52	-0.194	8.1	0.1	352.64	-0.01709
0. 4.40	10832.	1488.	130.57	130.47	8.73	183.08	-0.248	12.1	0.1	352.00	-0.01709
0. 5. 0	10543.	1437.	130.57	130.37	8.62	177.61	-0.305	16.7	0.2	350.73	-0.01709
0. 5.20	10254.	1410.	130.47	130.37	8.58	172.81	-0.181	0.7	0.1	350.55	-0.01709
0. 5.40	9964.	1405.	130.57	130.47	8.60	169.64	-0.160	6.0	0.1	351.68	-0.01709
0. 6. 0	9674.	1417.	130.57	130.47	8.61	166.30	-0.176	8.7	0.1	351.83	-0.01709
0. 6.20	9385.	1446.	130.57	130.27	8.60	162.42	-0.206	8.7	0.1	350.96	-0.01709
0. 6.40	9098.	1494.	130.57	130.47	8.58	157.86	-0.249	12.1	0.1	350.79	-0.01709
0. 7. 0	8817.	1560.	130.57	130.47	8.55	152.74	-0.260	12.2	0.1	351.04	-0.01709
0. 7.20	8542.	1648.	130.57	130.47	8.56	148.14	-0.176	0.5	0.1	350.49	-0.01709
0. 7.40	8272.	1755.	130.57	130.47	8.62	145.30	-0.119	0.5	0.1	352.57	-0.01709
0. 8. 0	8007.	1878.	130.47	130.37	8.71	143.19	-0.099	0.5	0.1	351.83	-0.01709
0. 8.20	7744.	2016.	130.57	130.47	8.83	141.62	-0.042	-5.7	0.1	351.67	-0.01709
0. 8.40	7485.	2168.	130.57	130.47	8.99	141.54	0.037	-9.7	0.1	354.68	-0.01709
0. 9. 0	7224.	2331.	130.57	130.37	9.18	143.08	0.108	-9.7	0.1	356.43	-0.01709
0. 9.20	6960.	2499.	130.57	130.37	9.36	145.73	0.152	-9.7	0.1	358.82	-0.01660
0. 9.40	6688.	2667.	130.57	130.47	9.52	148.79	0.129	-2.0	0.1	0.28	-0.01660
0.10. 0	6409.	2831.	130.57	130.47	9.66	150.88	0.088	-2.0	0.1	0.80	-0.01709
0.10.20	6124.	2993.	130.57	130.47	9.77	152.41	0.069	-2.0	0.1	1.10	-0.01709
0.10.40	5833.	3153.	130.47	130.37	9.86	153.70	0.061	-1.9	0.1	1.29	-0.01709

FIGURE 9 - PRINTER OUTPUT

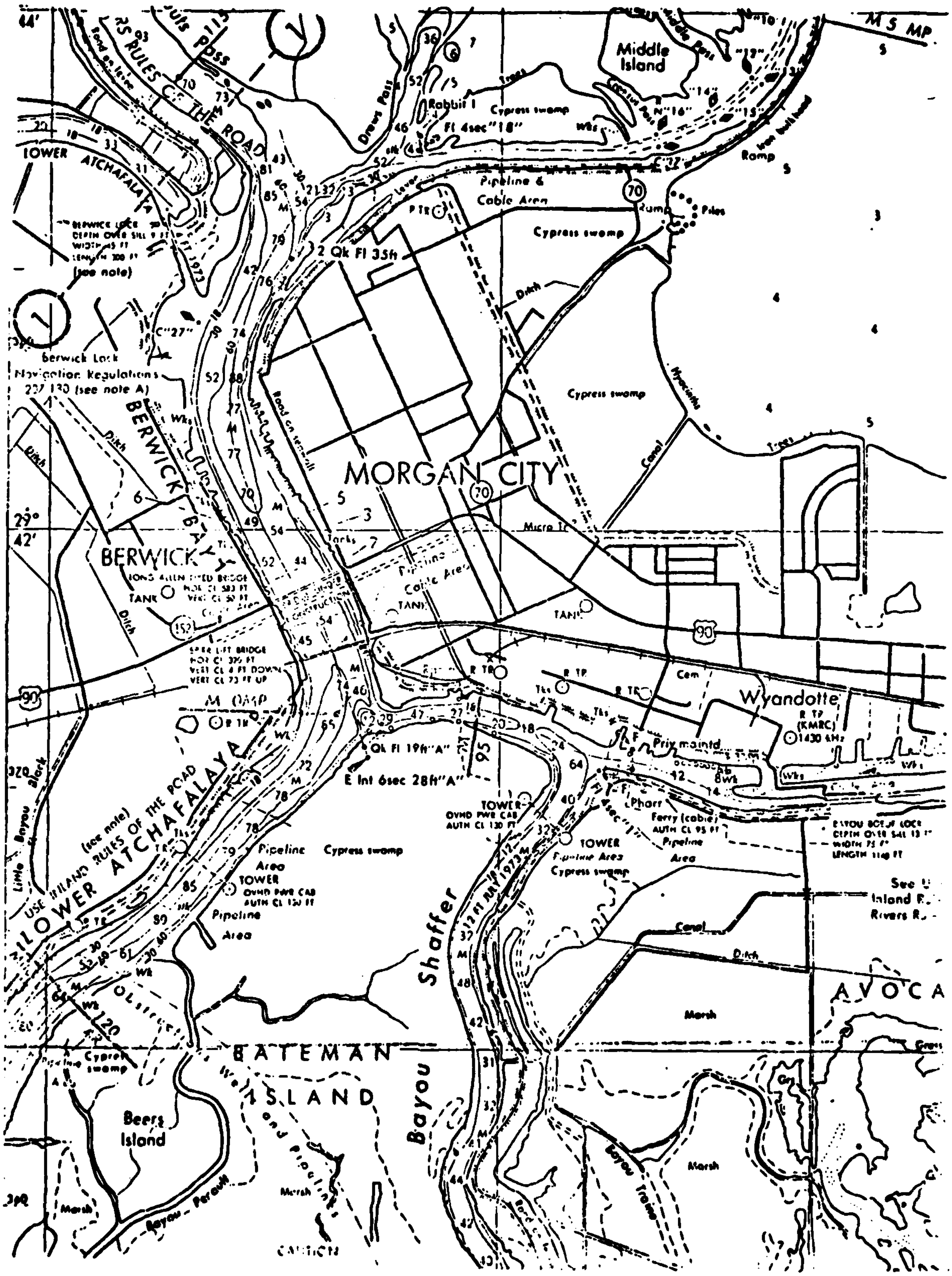


FIGURE 10 - BERWICK BAY, LOUISIANA CHART

Downstream Operation

- Entering Berwick Bay from the Port Allen route hold the sailing line shown and reduce speed to about half ahead.
- Entering Berwick Bay from Stouts Pass cross the river between 5 and 6 and favor left descending shore.
- Generally hold slow speed between 4 and 3 with intermittent use of power to stay on course and close to shore.
- At 3 current will set tow toward right descending shore if out too far in river.
- Cut point at Conrad Shipyard 3 in close to prevent current from catching stern of tow and rotating it out toward mid-river.
- Run between slow and half speed at 3 to maintain steerage and control.
- Should be shaped up by 2. Current tends to get tow out-of-shape between 2 and 3.
- At 1 either drive or hold half speed depending on conditions.
- Enter highway bridge at mid span or just to the right of mid span depending on current conditions.
- Current will shift at highway bridge and operator must expect a strong left hand draft between bridges.
- Favor right descending pier of railroad bridge to offset current and to prepare for sharp right hand bend in river just below bridge.
- Under some conditions with a long tow you must back and flank as soon as you clear the railroad bridge in order to line up for the passage down river.

Upriver

- In general operator can hold middle of river during upstream approach.
- At 2 slow down and line up with railroad bridge.
- Favor Berwick pier (left ascending pier) to offset current just below and between bridges.

FIGURE 11 - OPERATOR STRATEGEY

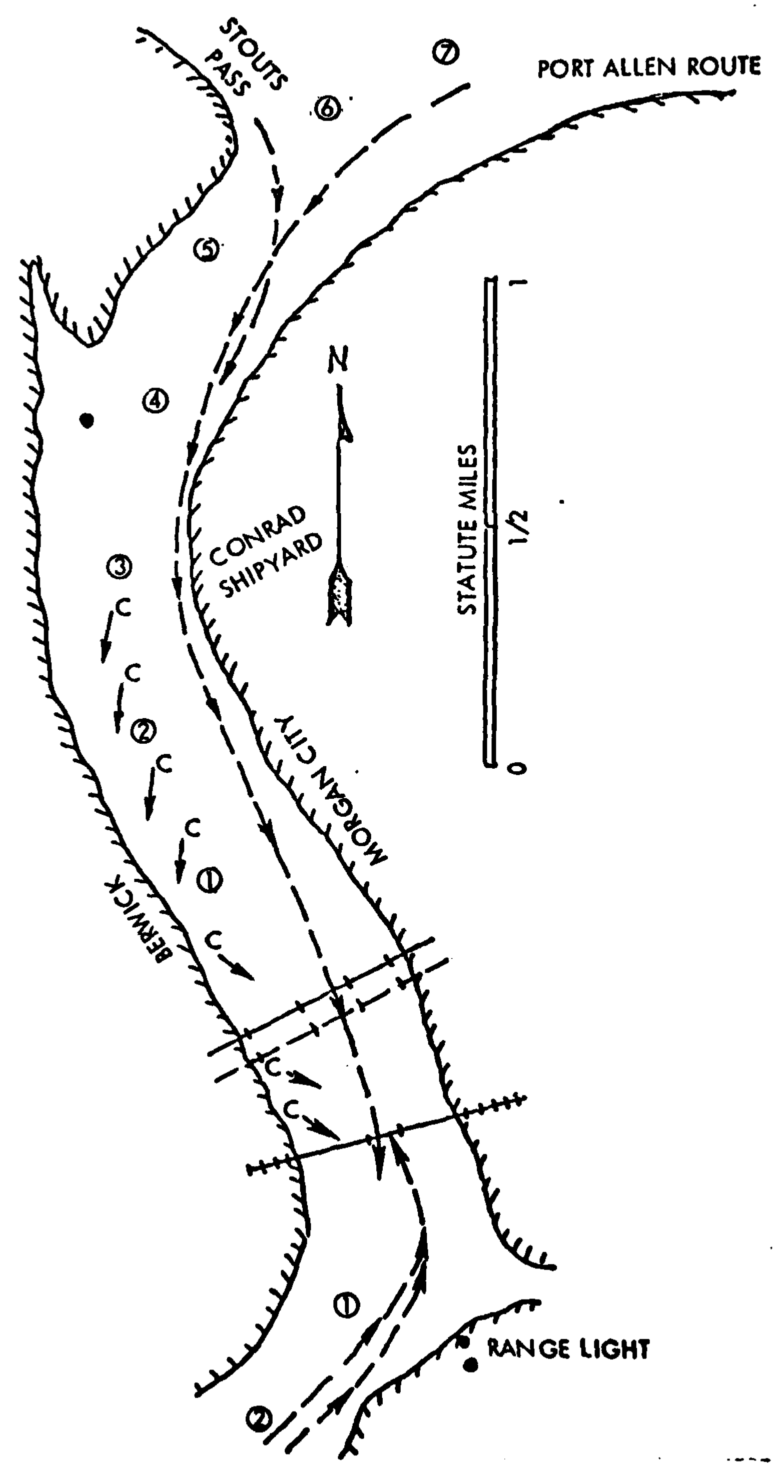
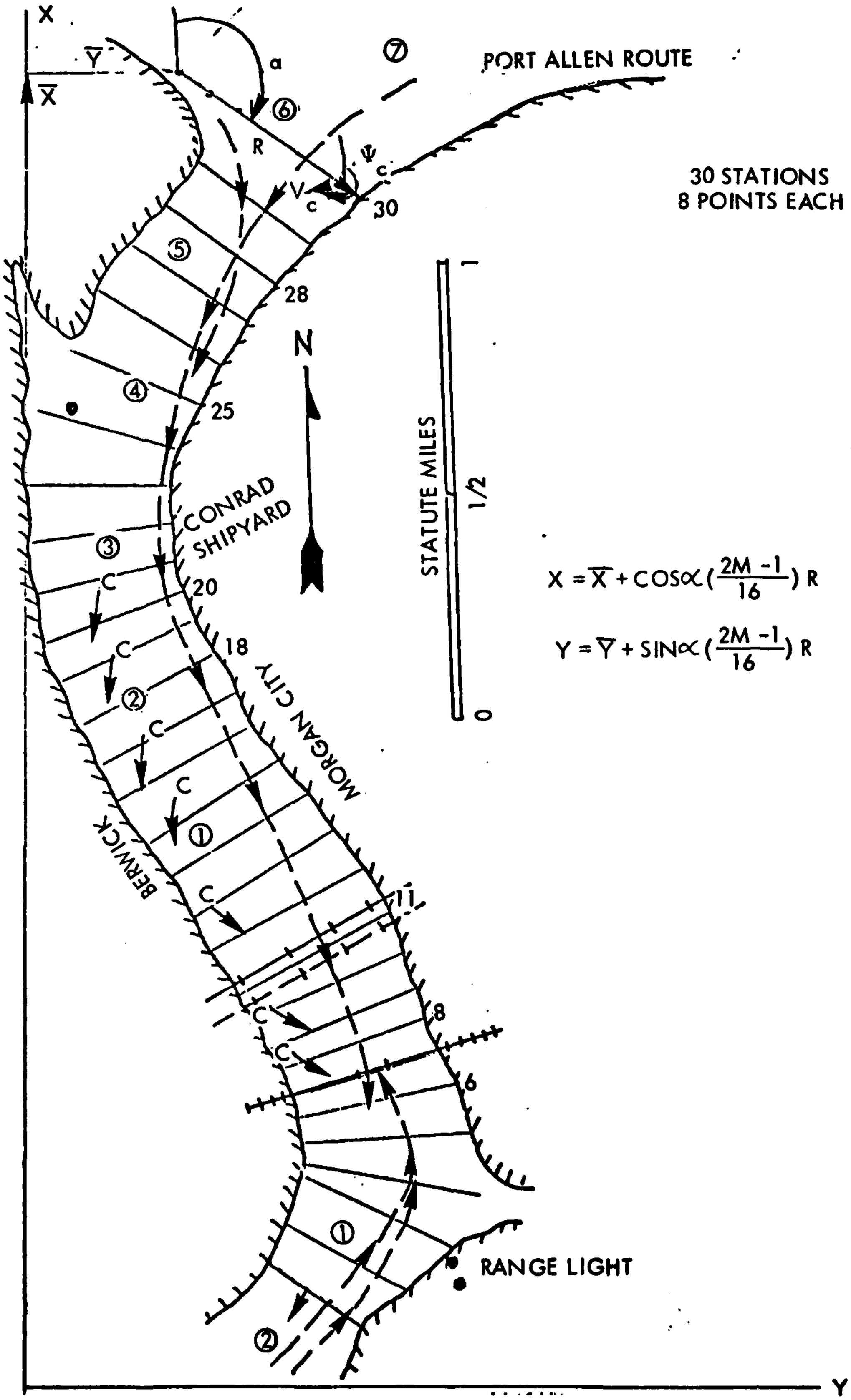


FIGURE 12 - BERWICK BAY PASSAGE



$$X = \overline{X} + \cos\alpha\left(\frac{2M-1}{16}\right) R$$

$$Y = \overline{Y} + \sin\alpha\left(\frac{2M-1}{16}\right) R$$

FIGURE 13 - CURRENT MAP

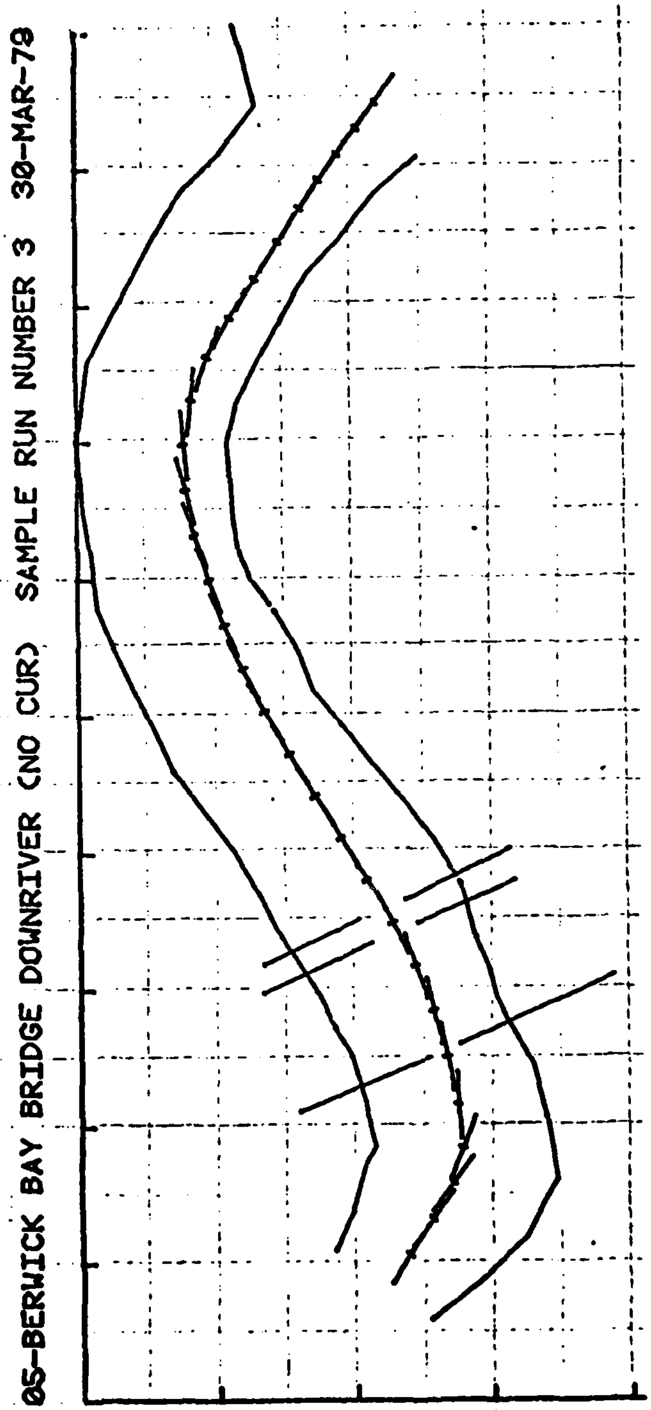


FIGURE 14 - NO CURRENT

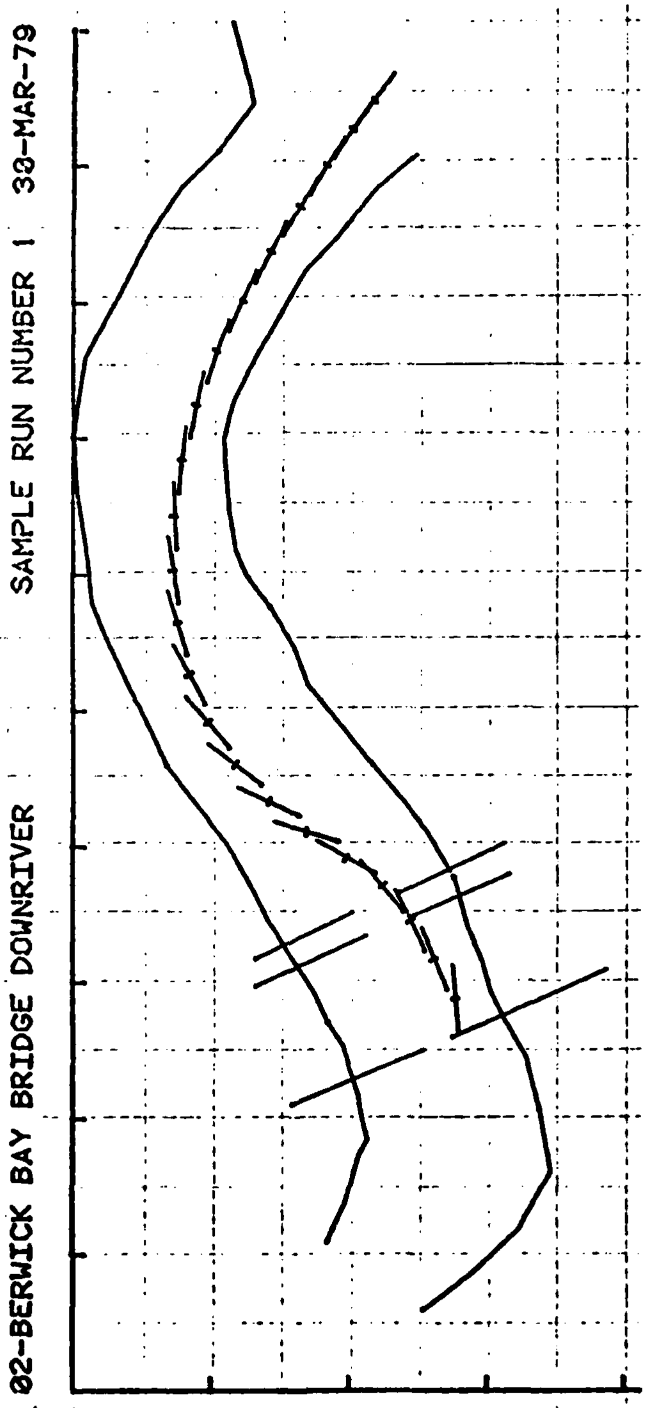


FIGURE 15 - EFFECTS OF UPSTREAM AND BRIDGE CURRENTS

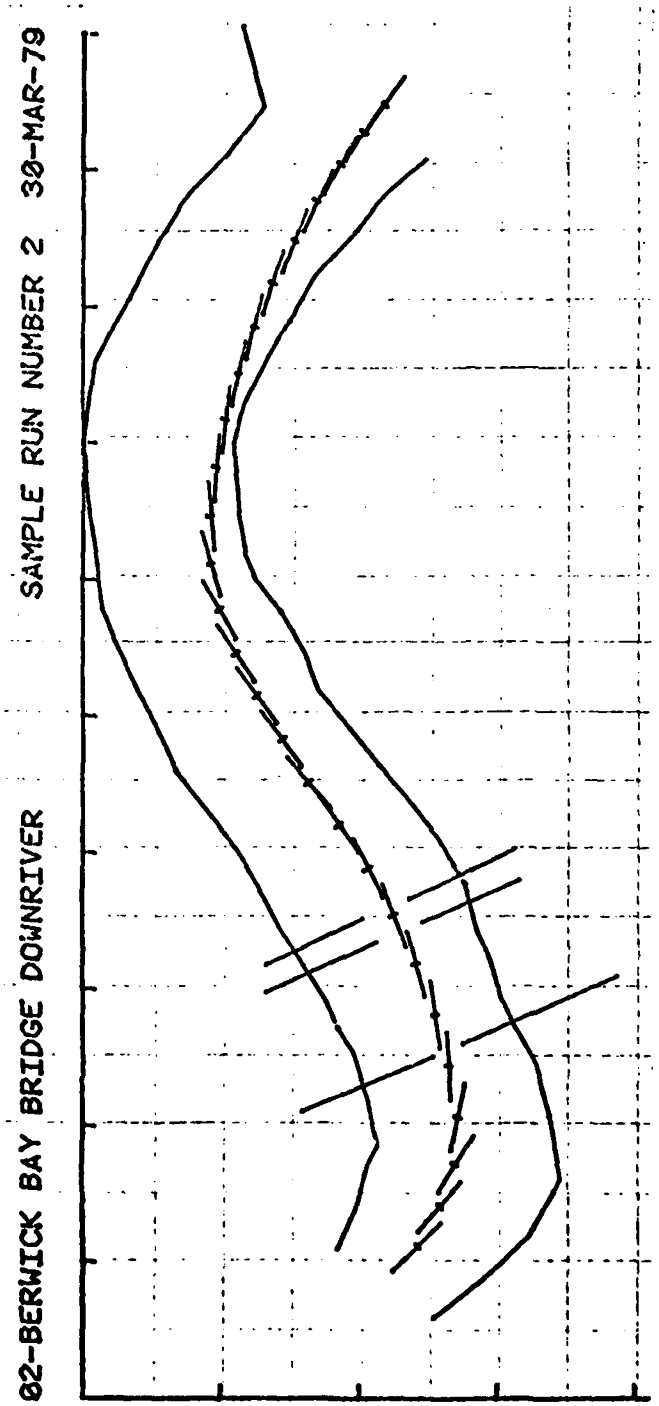


FIGURE 16- EFFECTS OF UPSTREAM AND BRIDGE CURRENTS

5.0 CONSOLE CONNECTIONS

A/D DEFINITIONS

0 - 15 Channels ± 5V

1 - WIRE A - Port Propeller RPM
2 - WIRE E - Starboard Propeller RPM
3 - WIRE B - Steering Rudders
5 - WIRE C - Flanking Rudders
7 - WIRE D - Thruster RPM
8 - WIRE F - Stop Switch

D/A DEFINITIONS

0 - 7 Channels ±5V

0 - WIRE J - Port Propeller RPM
1 - WIRE K - Starboard Propeller RPM
2 - WIRE L - Steering Rudder Angle
3 - WIRE M - Flanking Rudder Angle
4 - WIRE N - Thruster RPM
5 - WIRE P - Rate of Turn
6 - WIRE R - Heading
7 - WIRE S -

6.0 SIMULATOR OPERATION

RUNNING THE SIMULATOR

TURN ON

DEC PDP 11/34
DEC WRITER (300 BAUD, LINE, AUTO LF)
PLOTTER (LOAD)
4014 TERMINAL (RESET PAGE ON GLOW)
CONSOLE - SERVO RESET ON, RUN ON
TURN ON DISK 0

COLD START

CTRL/HLT, CTRL/BOOT TYPE:DL
@ STARTG

SCREEN

TYPE:	DATE	—	10-May-79
	TIME	—	20:30:15
	RUN	—	MAT10

FOLLOW INSTRUCTIONS

ENTER OPERATOR I.D. UP TO 20 CHARACTERS
MOVE DEC WRITER TO NEW PAGE
LOAD PLOTTER, REMOVE COVER AND SET PEN (780 x 1170 GRID)
CONSOLE SERVO OFF, RUN ON
RESET SCREEN
ON 4014

STOPPING

RUN OFF ON CONSOLE (STOP ON SCREEN)
TURN RUN ON AGAIN

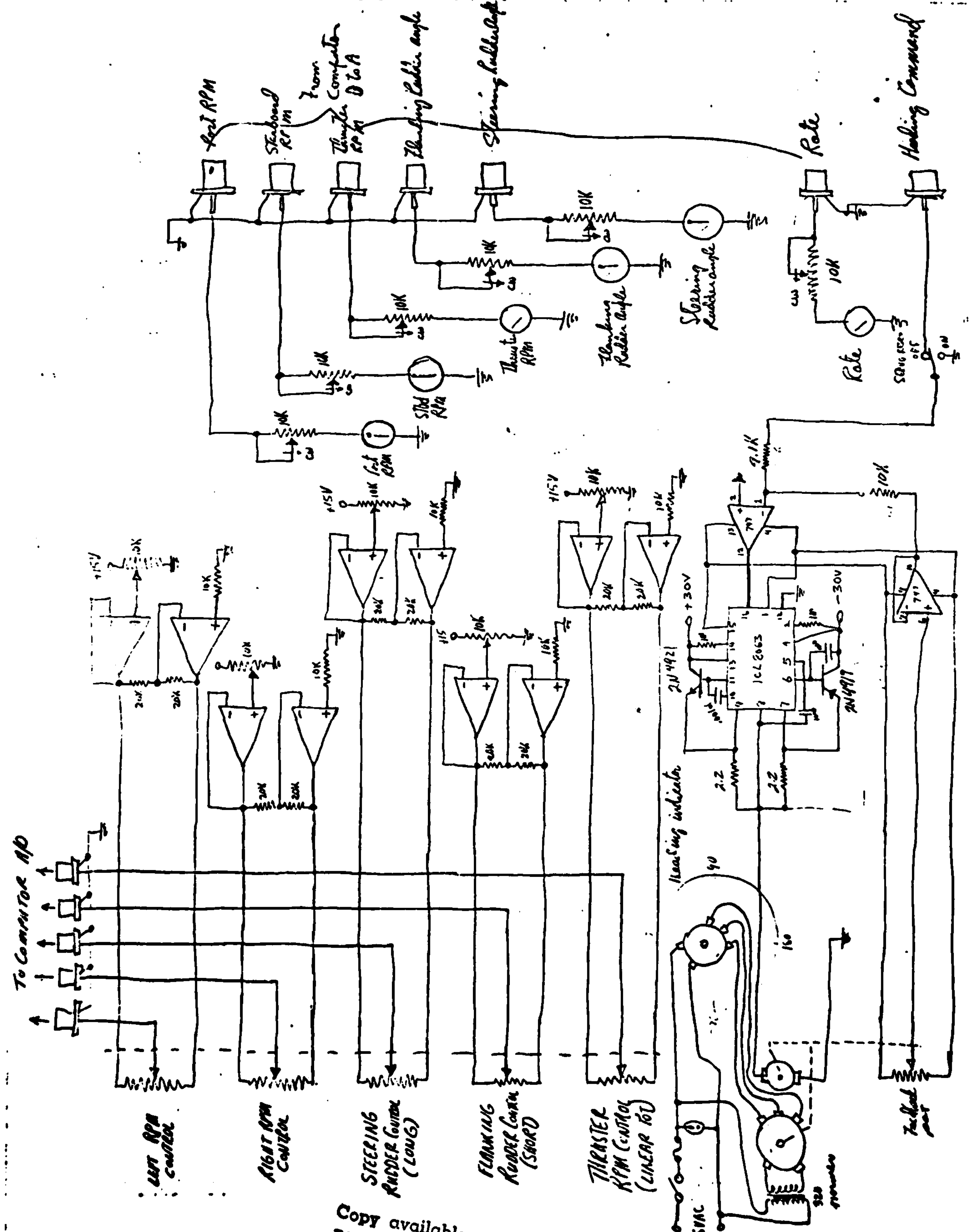
CHANGING THE PROBLEM

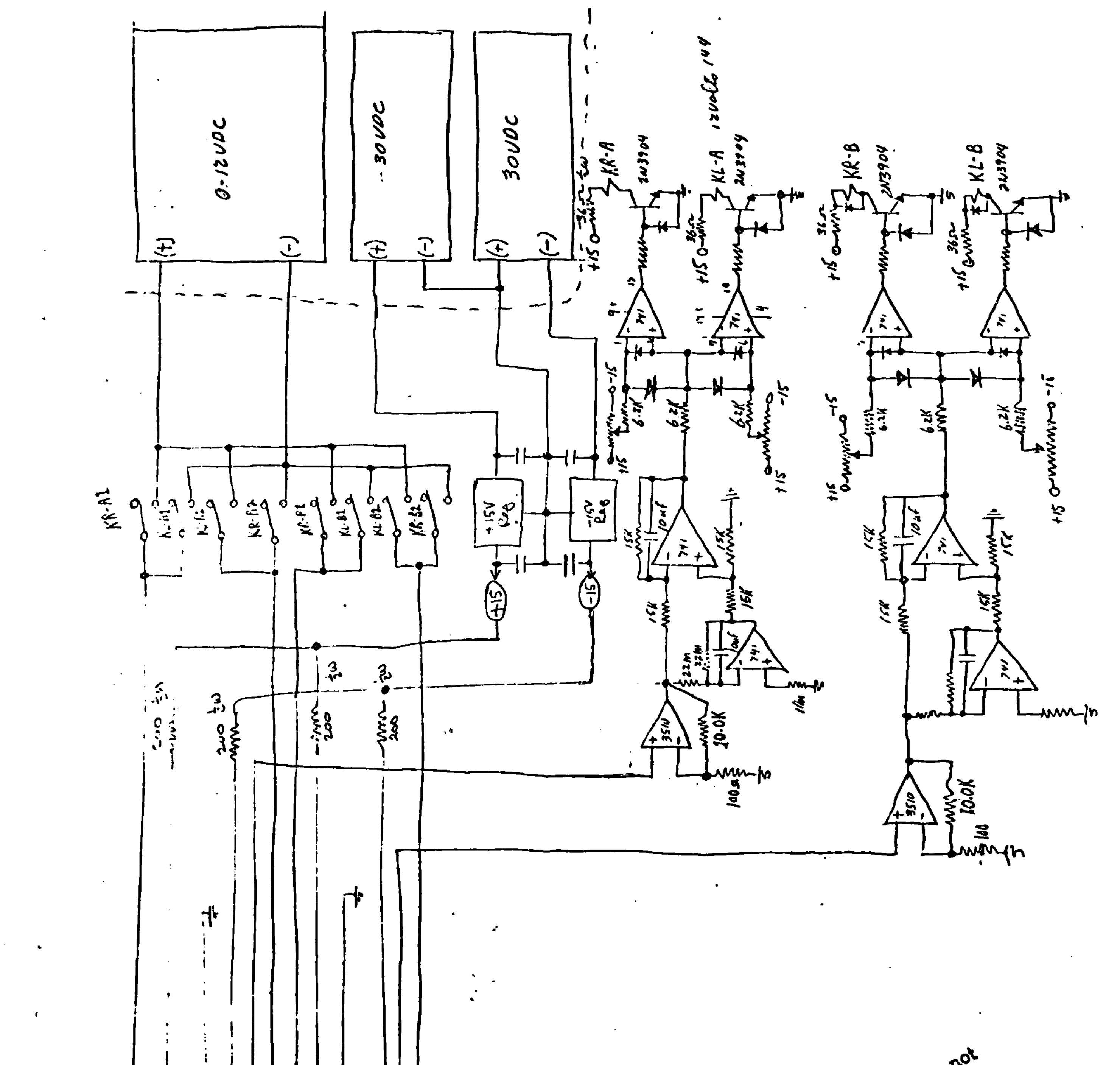
COPY — DTSXX.FOR — DTN10.FOR (XX= PROBLEM NUMBER)
FORTRAN — DTN10
@ MAT10

TURNING OFF

DISK 0 OFF (LOAD)
PLOTTER LOAD, PEN COVER ON
SERVO ON, RUN ON, CONSOLE OFF (AFTER HEADING = 0)
TEKTRONIX 4014 OFF
PLOTTER OFF
DEC WRITER OFF
DEC 11/34 OFF

7.0 WIRING DIAGRAMS


To COMPUTOR A/D
LEFT RPM CONTROL
RIGHT RPM CONTROL
STEERING RUDDER CONTROL (LONG)
FLANKING RUDDER CONTROL (SHORT)
THRUSTER RPM CONTROL (LINEAR POT)
ICL 8063
2N4921
2N4919
+30V
-30V
115VAC
Port RPM
Starboard RPM
Thruster RPM
Flanking Rudder angle
Steering Rudder angle
Rate
Heading Command


0-12VDC
-30VDC
30VDC
KR-A
KL-A
KR-B
KL-B
2N3904
741
3510
10.0K
+15
-15
KR-A1

8.0 SCENARIO PARAMETERS

Many of the variables in the input routines which are used to establish the operating geometry are described here in detail.

Subroutine DTL10 - Initial Conditions

XS, YS - Initial towboat position. XS is the horizontal co-ordinate in scene units, positive to the right, which is also the North direction of the scene. YS is the vertical co-ordinate in scene units, positive downward, which is the East direction.

PSID - Initial towboat orientation, with 0 being the North direction (headed to the right), 90 being East (headed down), etc.

NCCS - Number of current (and also scene) station to check first in current determination subroutine. Usually 1 or NCCT if boat starts at either end of the scene.

Subroutine DTM10 - Towboat Parameters

No scene parameters

Subroutine DTN10 - Scene Parameters

NCCT - Number of current/scene stations

SCALF - Scale factor used to allow current and scene parameters to be entered in other than scene units. The values of XX, YY, and RR used to set the scene are multiplied by SCALF in Subroutine SUB11 to change them to scene units for storage in the XW and YW arrays.

XX - Horizontal co-ordinate of a station starting point. Positive to the right. Units compatible with scene using SCALF.

YY - Veritcal co-ordinate of a station starting point. Positive downward. Units compatible with scene using SCALF.

RR - Radial co-ordinate of station. The scene boundary is at the ends of the RR line. One end is at XX, YY, and other at the end of RR. Units compatible with scene using SCALF.

PP - Orientation of RR with respect to XX, YY point, in degrees. PP equal to 270•implies that RR is in an upward vertical direction, so that the scene boundary is at XX, YY and XX, YY-RR. The end points of the NCCT stations are connected to form the scene boundary.

VC, PSIC - Current values in ft/sec and direction in degrees.
VC(1) to VC(8) are the eight values at Station 1
VC(9) to CV (16) at Station 2, etc.

NPPB - Number of straight line segments (up to 10) drawn on scene. Co-ordinates are in scene units; SCALF is not used to change them. XB(1), YB(1) is the starting point of line 1, XB(2), YB(2) is the end of this line.

NPPT - Number of positions plotted on graphic output device for every 1 plot of towboat position on plotter.

NCCS - If NCCS is set to -2, no current is assumed by the current subroutine CURT. This saves time by not requiring CURT to search for the current values at each calculation interval.

DATE

ILME

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